



General Aerodynamic Principles

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Introduction

Aerodynamics being the study of how air interacts with an object was discovered to be a way of improving efficiency in automobiles from fuel economy to lateral acceleration.

Background

Air interacts with a vehicle by applying pressure producing a force perpendicular to the surface.

Pressure is the force applied per unit of area.

$$Pressure = \frac{Force}{Area} (N/m^2)$$

There are three types of energy in a fluid, the above-mentioned pressure, kinetic energy and potential energy and considering the first law of thermodynamics we know that energy cannot be destroyed or created, it can only be transformed. So, we can take from this is that pressure and kinetic energy must be inversely proportioned in order for the energy within the fluid to be constant. This is Bernoulli's Principle.

More Speed = Less Pressure

Less Speed = More Pressure

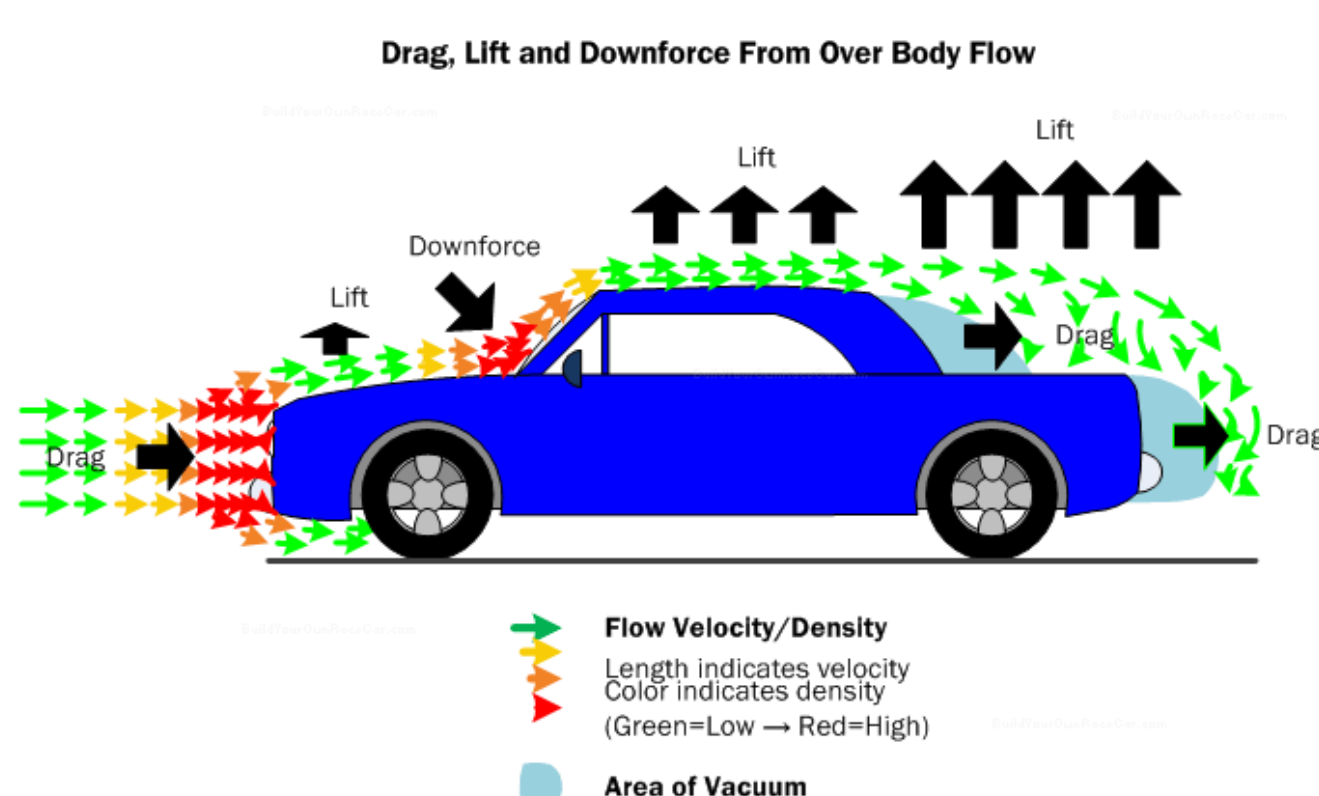


Image 1 – How Air Pressure Affects a Vehicle

This pressure creates two types of forces, one affecting the vehicle vertically, and one other horizontally, which are lift, and drag, respectively.

$$Lift\ Force = C_L \times \frac{1}{2} \rho V^2 \times A$$

Acting horizontally, we have drag which can be created by frontal pressure, skin friction and rear vacuum, all of them opposing motion.

$$Drag\ Force = C_D \times \frac{1}{2} \rho V^2 \times \text{Frontal Area}$$

C_D being the coefficient of drag of the shape, the lower the number the more streamlined said shape is.

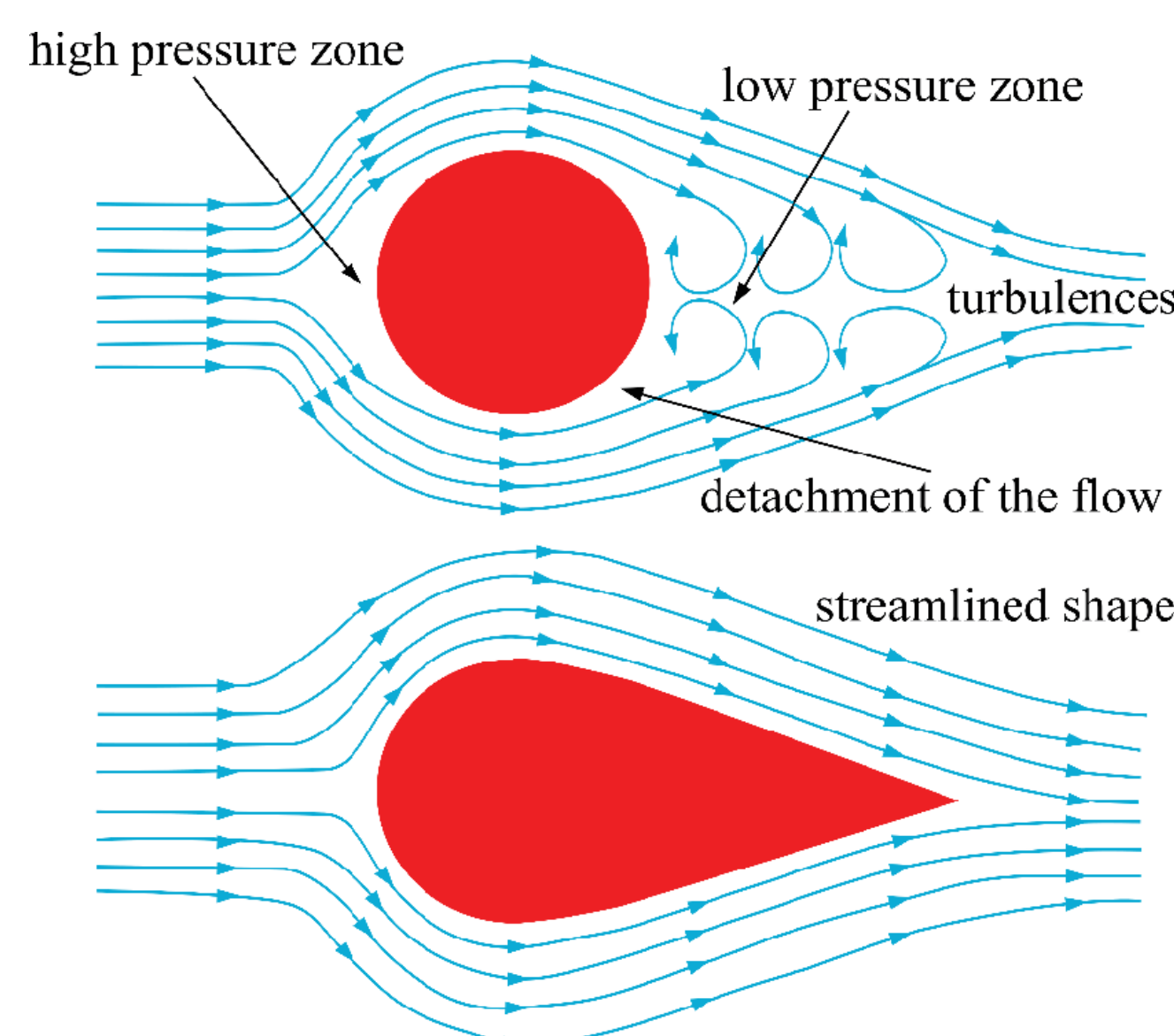


Image 2 – Streamlining of Shapes

Similarly to the centre of gravity which is the point in which weight is evenly dispersed, the average point of pressure is called centre of pressure, this is the point where aerodynamic forces act upon.

The relation between CoP and CoG defines the stability of the vehicle. Ideally, you would want CoP behind CoG.

$$CoP = \frac{Front\ Axle\ Aero\ Load}{Front\ Axle\ Aero\ Load + Rear\ Axle\ Aero\ Load} \times 100$$

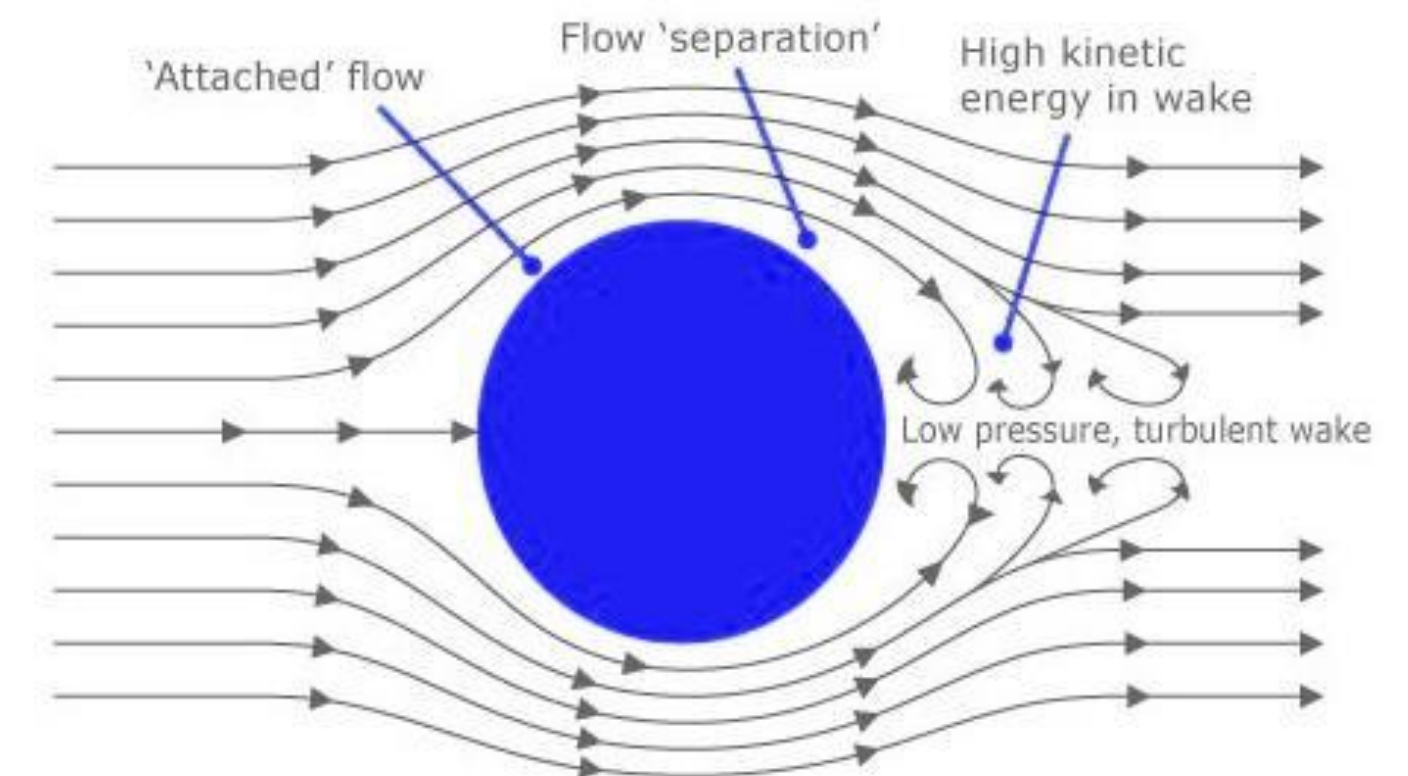


Image 3 – Flow Separation and Turbulence

When flow reaches the back of the car, the sudden change in shape may develop a low-pressure zone creating turbulent air causing increased drag and it should be kept to a minimum via the use of streamlined designs, spoilers and diffusers.

Discussion/Conclusion

It is very rarely that we see a subject within the automotive field that can have a significant impact in such a broad spectrum of areas from making motorsport cars more stable and corner faster, to helping fuel-efficiency in road going cars, to reducing intrusive wind noise in the most silent of electric cars. The applications are endless, especially in a world of ever-changing regulations pushing engineering to find solutions to narrow the environmental impacts and be on path to sustainability, aerodynamics will play a big part in keeping the automotive industry going forwards for decades to come.

References

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